Sandia National Laboratories

Fact Sheet

Hydrogen and Metallurgical Science Department

Physical and Engineering Sciences Center

Decades of Expertise on Hydrogen Behavior

Since our founding charge to secure the nation's nuclear stockpile, Sandia has necessarily developed an unparalleled understanding of hydrogen's unique properties and effects. The scientists and engineers in our Hydrogen and Metallurgical Science Department continue to advance fundamental knowledge of how hydrogen, its isotopes, and helium interact with metals and other materials. Applications range from nuclear weapons to fusion reactors to the emerging hydrogen economy and everyday commercial uses.

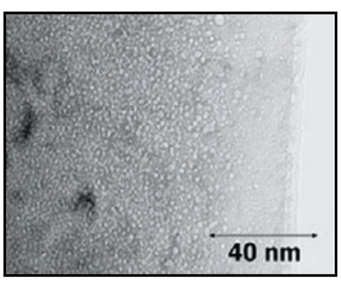
This department also boasts some of the nation's leading metallurgists, who draw on this knowledge of hydrogen behavior to explore new concepts for corrosion-resistant coatings, multiscale alloys, thin-film adhesion, and joining techniques.

Hydrogen Effects on Mechanical Properties of Materials

Through 40 years of designing stainless steel pressure vessels to store gaseous hydrogen isotopes, we have acquired a deep understanding of how hydrogen can affect the materials it contacts. Our group maintains sophisticated capabilities for measuring the tensile and fracture mechanics properties of materials exposed to high-pressure hydrogen gas.

Helium Bubbles

Anticipating the next generation of tritium storage, we are modeling helium bubble density and size distribution in various materials. We seek a better understanding of helium trapping and bubble nucleation near surfaces to provide accurate predictions of helium retention in nanoporous and thin-film materials.



Helium bubbles are evident in this TEM cross-section of He-implanted metal.

Tritium Production

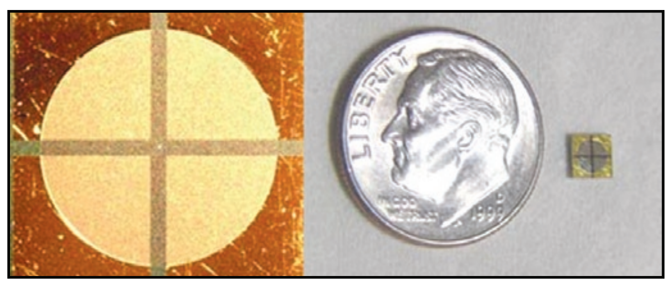
In collaboration with NNSA and PNNL, our group is designing the tritium-producing burnable absorber rods (TPBARs) used in the Watts Bar reactor to produce tritium for the nation's stockpile. We are developing computer codes to model tritium's release from the lithium ceramic and its eventual absorption by the nickel-coated zirconium getter inside the TPBARs. We're also conducting experiments to produce kinetic and equilibrium data needed for the computer models.

Gas Transfer Systems

We provide mechanical testing and modeling support for many gas transfer system components. In addition, we model tritium uptake in the materials, its subsequent decay to helium, and the overall effects of both tritium and helium on the system's mechanical properties. Our models address the latest nanostructured materials being incorporated into new system designs.

Hydrogen Sensors

We are developing solid-state hydrogen sensors in the form of metal-insulator-semiconductor (MIS) devices that change their electrical properties upon exposure to hydrogen. We're particularly interested in using these



Left: Our versatile MIS sensor chip contains four individual hydrogen sensors; the sensing areas are the pie-shaped segments. Right: Dime shows scale of sensor chip.

sensors to (1) detect small leaks in hydrogen storage vessels and supply lines, (2) monitor the hydrogen gas generated by degrading materials in power transformers (and thereby avoid power outages due to transformer failure), and (3) analyze the energetic flux of hydrogen ions emanating from plasmas in magnetic-confinement fusion experiments.

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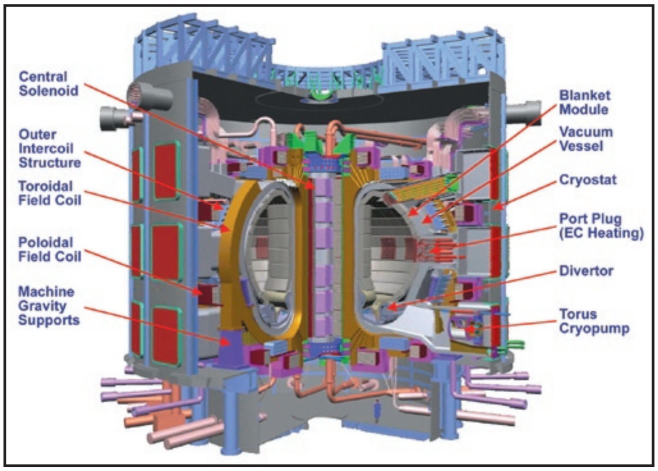
Hydrogen Isotopes for Fusion Reactors

For more than 30 years, Sandia has been a leading authority on plasma-surface interactions for fusion applications. We maintain state-of-the-art laboratories and experimental devices to explore processes such as physical and chemical sputtering (erosion by plasma interactions) by hydrogen isotopes, as well as tritium retention and migration.



ITER schematic: Our department leads the U.S. effort on joining plasma-facing materials to underlying structures for the International Thermonuclear Experimental Reactor (ITER), an international collaboration to build the first magnetic fusion device to demonstrate "breakeven," where energy production equals or exceeds energy input.

Besides isotope research, we're leading the U.S. effort on joining plasma-facing materials to underlying structural materials for the International Thermonuclear Experimental Reactor (see diagram). As an example, the low-Z material beryllium used as the plasma-facing first-wall material must be joined to the underlying water-cooled copper. Interfacial materials such as titanium must be used to prevent copper and beryllium from interdiffusing to form brittle intermetallics.

Permeation Barriers

In all applications, it is desirable to minimize permeation (loss) of hydrogen gas to the environment. While important for hydrogen in the hydrogen economy, it is imperative for radioactive hydrogen (tritium). We are developing coatings such as silicon carbide, alumina, erbia, and gold that can minimize tritium release. Such barriers could be used for gas transfer systems or for tritium breeding blankets on fusion reactors.

Corrosion-Resistant Coatings

As the lead laboratory characterizing materials for the DARPA/DOE–sponsored High-Performance Corrosion-Resistant Amorphous Metals Program, we're examining the correlation between fabrication processes and corrosion performance for materials to store spent nuclear fuel and for materials used in naval applications.

Multiscale and Nanocrystalline Alloys

Smaller grain size allows higher strength-to-weight ratios, yet nanocrystalline materials, the strongest by weight, may fall short on other mechanical properties. Our group has generated nanocrystalline alloys with a bimodal grain structure—i.e., micrometer-scale grains embedded in a matrix of nanoscale grains—that combine a ductility close to that of conventional alloys with the strength of nanocrystals. We're investigating the thermal stability and fracture toughness of these bimodal structures, with an emphasis on weldable aluminum alloys.

State-of-the-Art Materials Characterization

Our research depends on our ability to see materials in ever greater detail. Accordingly, we maintain extensive laboratory facilities to characterize material structure and behavior. Capabilities include SEM, TEM, HRTEM, 3D TEM, EMPA, XTM, nuclear spectroscopy, Auger spectroscopy, low-energy ion beam analysis, and phase contrast imaging. We continue to push toward ever finer resolution, upgrading our capabilities as new options become available.

Learn more at: http://public.ca.sandia.gov/8700

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